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Zero CO_2 emissions aviation

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The present situation

Air transport's climate-harming emissions have grown substantially from year to year over decades and, with the exception of 2020, they seem likely to continue to do so. Aviation emissions are the Achilles' heel of the tourism industry and tour operators, tourism authorities and destinations need to galvanise efforts to influence air transport partners to enhance mitigation action, in some cases as a matter not just of presenting green credentials but of tourism sector survival.

It is currently unclear when air traffic will return to 2019 levels and whether future air traffic growth rates will be lower than in the past, but it remains a likely scenario that without markedly more effective regulation damaging emissions from air transport will at least double 2019 levels by 2050. If aviation is to make its requisite contribution to the Paris Agreement targets, its CO_2 emissions would have to be reduced by 2030 to half 2019 levels and by 2050 to zero (not "net" zero, which includes out-of-sector carbon offsetting, capture and storage). Furthermore, recent peer-reviewed climate research has shown that non-CO_2 impacts of aviation are significantly larger than those of CO_2, but they have yet to be included in mitigation measures.

Technology and operational measures continue to improve aircraft fuel efficiency but, even without any increase at all in traffic, these emissions continue to be pumped into the atmosphere where they may stay for centuries – they do not counter the climate imperative but rather continue to exacerbate the crisis. Many efficiency measures also reduce the costs of flying, lead to additional growth in traffic and emissions.

Carbon offsetting is not an answer. It shifts the moral responsibility for carbon reduction to someone else, the quality of offset units is heterogeneous and far from guaranteed, and studies have shown that the majority of even those of the highest standards simply do not work. A variant of offsetting, also questionable in the general context, is to set Carbon Capture and Storage (CCS) against emissions, although there may be an exception when the captured carbon is used to create e-fuels (see below).

Neither are the vast majority of biofuels a solution when assessed on a full life-cycle basis and emissions reduction over kerosene. A possible limited and temporary exception is biofuels from waste, which face increasing limitations of scale, there is not enough waste available.

Some potentially significant contributions

Synthetic e-fuels have "drop-in" capability for all contemporary jet aircraft types. However, the current production is negligible, they require a large amount of "green" power to produce the liquid fuel, and their cost is currently at least three times as high as that of conventional jet fuel and is likely to remain so. E-fuels could nevertheless become a viable alternative given the application of blending legislation (for example a required proportion of well-defined low carbon fuel supplied at an airport with stepwise increases every five years) and they could make a significant contribution as early as 2025.

Electric aircraft come in two fundamentally different kinds, those with batteries and those with hydrogen plus fuel cells as energy source. Batteries may develop for ultra-short range small aircraft in the market of aerial taxis and urban transport and to replace ferries in areas with stretches of water, at distances up to 100-150 km. These aircraft can reduce emissions to zero, assuming the electric power input itself is “green”. But for contemporary commercial air transport, batteries are far too heavy and will not become an efficient solution. The other electric option, hydrogen-fuel cell, is far more promising, for example ZeroAvia is currently test-flying a 6-seater and has finance for developing a 19-seater (Osborne, 2019).

Another possibility now on the table, notably as proposed by Airbus, is to develop hydrogen-burning jet aircraft. These require substantial redesign from contemporary aircraft, *inter alia* because while the energy density of hydrogen is much greater than kerosene in terms of mass, it is several times less so in terms of volume and therefore requires much larger storage capacity. There is some scepticism as to the feasibility of production of such aircraft, but Airbus plans to have them in service by 2035 at the short and medium haul, with passenger capacity up to 200 seats. Fuel-cell aircraft provide the environmentally superior technology because these aircraft will have only liquid water as exhaust while hydrogen jets will emit water vapour (with consequent increase in contrails) and nitrogen oxides.

For all three technologies, e-fuels, fuel cell aircraft and hydrogen-burning jets, hydrogen is a common denominator. However, some 95% of the world’s hydrogen is presently produced from fossil fuels, resulting in carbon emissions. The product is known as “grey” hydrogen when these emissions are released into the atmosphere, with “blue” hydrogen meeting a low-carbon threshold because the CO_2 emitted in the reaction is captured for storage underground or reuse. “Green” hydrogen not only meets the low-carbon threshold but is generated using renewable energy sources such as hydro, solar or wind power for electrolysis, splitting water or ethanol molecules into their constituent elements. While “green” hydrogen is gaining traction, competition for its limited supply will be increasingly fierce and there is a need for prioritization for use in aviation which, unlike most other sectors, presently has no ready alternative to fossil fuels.

Given the lengthy time frame before there is extensive application of electric/hydrogen-powered aircraft, e-fuels will need to be widely developed and disseminated if the aviation sector is to have any chance of achieving carbon zero or even net-zero by 2050 in line with other sectors and the Paris Agreement climate imperative. A chronological scenario of the combined impact of hydrogen and e-fuel is illustrated by Figure 1, which shows global aviation greenhouse gas emissions as modelled up to the end of this century. The Reference scenario (in red) assumes Paris compliant carbon prices as set by the ICAO CORSIA carbon offsetting program (ICAO, 2021) and no specific measures for aviation (i.e., business as usual). As shown by the two Paris agreed global emission lines (in solid and dashed green) including all sectors, aviation alone means the global emission goals cannot be met from 2055 (1.5 ° C) and 2075 (2.0 ° C). The Hydrogen, fuel cell, electric scenario (in orange) shows that the initial effect will be small because the shortest haul aircraft fleet will be replaced first and they have a relatively small share of emissions. Only after about 2070, when the larger and longer haul aircraft will become available, do the emissions start to reduce. The E-fuel scenario (in blue) assumes an uptake of the costly e-fuels by way of government blending mandates (regulations). This scenario can become effective much earlier but will not entirely reduce emissions to zero. Also, it will need very large amounts of renewable energies. Therefore, a combination scenario (in dark green) is necessary to reduce emissions to zero.

All these scenarios still have a relatively high cumulative carbon footprint integrated over the whole time from 2021 to 2100.

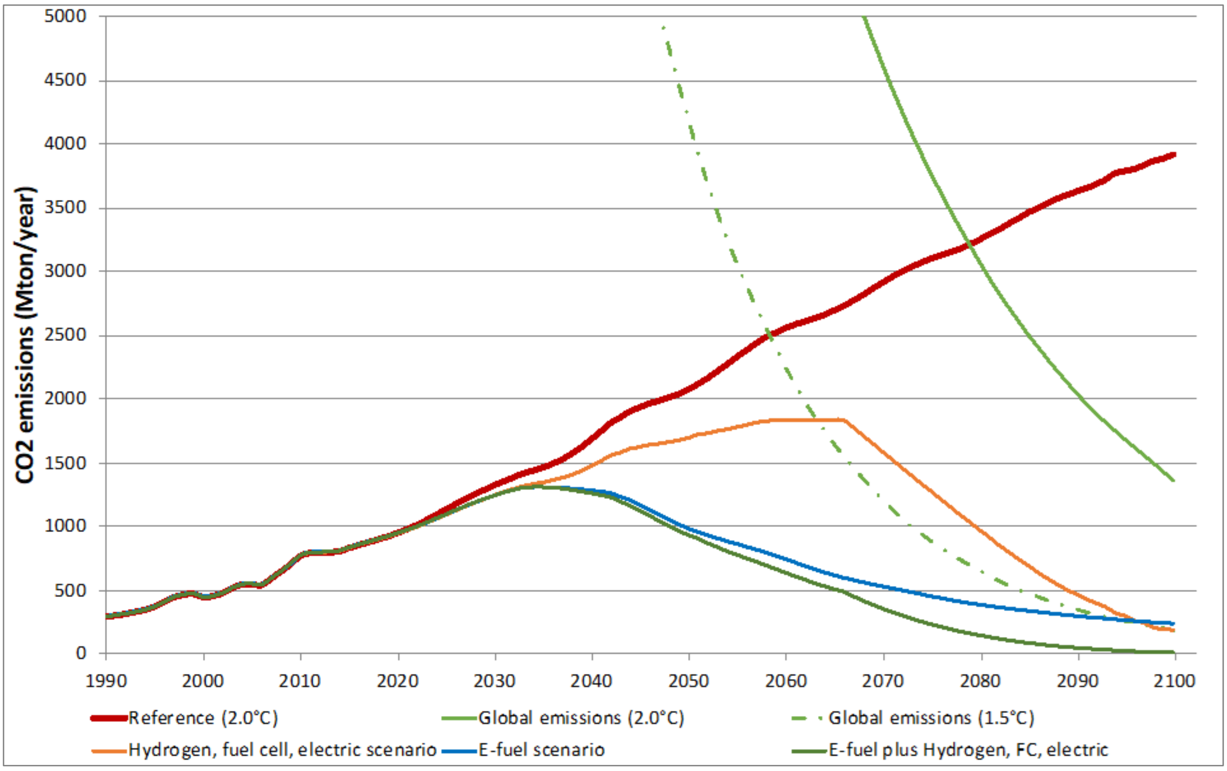

Figure 1: Scenarios for the global CO_2 emissions from aviation and the emissions as required by the two Paris 2015 Climate Agreement goals (based on calculation with the model created by Peeters, 2017).

The best approach to achieving the necessary reductions would be through policies that decrease the growth rates for the most critical segments of air transport. Such policies could contain smart taxes and subsidies, an effort to improve alternative low-energy transport modes like electric rail, and by passengers adapting to achieve their purpose of travel goals at shorter distances.

Existing tax exemptions on fossil fuels for air transport, along with other sector-specific subsidies, are both discriminatory and a significant hurdle against investment in alternative fuels, power sources and aircraft types. These exemptions should be removed and the resulting levies aligned with those for other sectors but ring-fenced for e-fuel and hydrogen power research and development, both public and private (to avoid legal constraints, the exemption withdrawal might be done in the form of an environmental charge).

Carbon labelling of transport is already available and should be emphasized to promote the understanding of travellers and shippers as to the contribution that air transport makes to climate change and, in complementarity to industry-related mandates and actions, to give them responsibility, accountability and choice regarding their emissions. Once carbon labelling is well established individual travellers and shippers could be subject to carbon taxation, with revenues again ring-fenced for use towards e-fuel and hydrogen-powered aircraft development. Some carriers already offer the option to passengers of contributing to “sustainable aviation fuel” (a form of in-sector offsetting).

Thus, the main policy needs for the required reduction of aviation emissions - aside from reduction in flying, which may become inescapable absent other actions - involve removal of subsidies, effectively-designed carbon pricing, clear e-fuel mixing mandates and a focus on the development of "green" hydrogen-sourced e-fuels and hydrogen-powered aircraft, along with fuel cell electric aircraft (not batteries) for the short haul. These should be integral to policy planning and the general investment environment. A long-term, stable policy framework with sufficient incentives and the necessary confidence for major investments in production is required. As most of the above-mentioned policies are at national level, in some cases co-ordinated regionally, it is important to create national incentives to implementation and not be constrained at the global level. The following outlines a way forward.

A strategic scenario

Action by COP26

The UNFCCC should:

a) include international aviation emissions into Nationally Determined Contributions, thereby giving individual Parties incentives through direct accountability and associated freedom to act, putting aviation mitigation activities in the context of varying national circumstances (international aviation emissions are presently treated indirectly by Parties on a global, "lowest common denominator" sectoral basis)
b) provide direction on not only allowing but encouraging greater ambition by individual Parties, complementary but in addition to any multilateral sectoral arrangements on aviation emissions reduction (on the basis of "bottom up" rather than current "top down") and empowering individual Parties to apply fossil fuel levies and low carbon fuel blending mandates
c) set a target of zero carbon 2050 for international aviation with intermediate targets to be established at five-year intervals,
d) address non-CO2 emissions from international aviation (including contrails) with a view to adoption of targets.

Associated policy

Governments, unilaterally or in agreement with others, should:

a) set national targets for aviation emissions reduction and provide for penalties on air carriers, airports or fuel suppliers which do not meet these targets)
b) remove fossil fuel tax exemptions for air transport and align resulting levies with those for other sectors but ring-fence them for e-fuel and hydrogen power research and development, both public and private (to avoid legal constraints, the exemption withdrawal might be done in the form of an environmental charge)
c) define clearly and transparently what is an acceptable Sustainable Aviation Fuel (SAF) for flights within and from their territories (any bio-based fuel should not be subsidized and should be subject to rigorous evaluation from the full life-cycle and net emissions reduction perspectives before it is accepted as a SAF)

d) establish effectively designed (and consistent with electric and hydrogen fuel policy), progressive and legally binding SAF blending mandates for fuel suppliers, airports and/or air carriers with principal place of business in their territories
e) implement a policy framework that prioritizes aviation SAF production and use over road and maritime transport alternative fuels
f) agree on green investment credits for airframe and engine manufacturers, including new entrants in the field of electric powerplants, against projected emissions target standards and with penalties for non-achievement
g) consider air transport, tourism, and air trade collectively (rather than as the current tendency to treat them in separate silos) with combined economic, social and environmental prosperity as the goal
h) make emissions reduction policy integral to the broader economic regulation and operations of air transport (for example in terms of non-stop and direct air transport services versus hub and spoke), including reductions in flight operations and airport expansion as may become required to meet climate change mitigation objectives.

Governments and industry should each:
a) focus on "green" hydrogen as both for a source of power for e-fuels and for the evolving development of on-board hydrogen powered aircraft
b) strongly discourage out-of-sector carbon offsetting in favour of real in-sector reductions in emissions (or of offsetting directly to e-fuel and hydrogen-powered aircraft evolution)
c) provide continued support for e-fuel and hydrogen power research and development, including progress in feedstock supply chains and new and innovative production technologies, while encouraging public-private partnerships and giving producers financial incentives, with priority allocation to the air transport sector (creation of a revenue stream from fossil fuel levies and generation of credits may be one route)
d) work towards carbon labelling of air transport (broken out from but included in comprehensive travel and tourism carbon labelling)
e) promote the understanding of travellers and shippers as to the contribution that air transport makes to climate change and, in complementarity to industry-related mandates and actions, give them responsibility, accountability and choice regarding their emissions.

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